Emotion
2009, Vol. 9, No. 6, 865–873

1528-3542/09/$12.00 DOI: 10.1037/a0017749

Dissociating Emotion-Induced Blindness and Hypervision

Bruno R. Bocanegra and René Zeelenberg
Erasmus University Rotterdam, Rotterdam, the Netherlands

Previous findings suggest that emotional stimuli sometimes improve (emotion-induced hypervision) and sometimes impair (emotion-induced blindness) the visual perception of subsequent neutral stimuli. We hypothesized that these differential carryover effects might be due to 2 distinct emotional influences in visual processing. On the one hand, emotional stimuli trigger a general enhancement in the efficiency of visual processing that can carry over onto other stimuli. On the other hand, emotional stimuli benefit from a stimulus-specific enhancement in later attentional processing at the expense of competing visual stimuli. We investigated whether detrimental (blindness) and beneficial (hypervision) carryover effects of emotion in perception can be dissociated within a single experimental paradigm. In 2 experiments, we manipulated the temporal competition for attention between an emotional cue word and a subsequent neutral target word by varying cue–target interstimulus interval (ISI) and cue visibility. Interestingly, emotional cues impaired target identification at short ISIs but improved target identification when competition was diminished by either increasing ISI or reducing cue visibility, suggesting that emotional significance of stimuli can improve and impair visual performance through distinct perceptual mechanisms.

Keywords: emotion, masking, visual word identification

Recent studies indicate that emotion affects the processing of visual information (Dolan, 2002; Fox, Russo, Bowles, & Dutton, 2001; Öhman, Flykt, & Esteves, 2001; Phelps, 2006). Results from positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) studies (Lang et al., 1998; Morris et al., 1998; Vuilleumier, Richardson, Armony, Driver, & Dolan, 2004), show that the emotional significance of the presented stimuli modulates activation of the visual cortex. In addition, results from event-related potential (ERP) studies show that, compared with neutral stimuli, pleasant and unpleasant stimuli are associated with early differential activation over occipital sites, suggesting that the affective content of both word and picture stimuli influences visual processing (Keil, Ihssen, & Heim, 2006; Kissler, Herbert, Peyk, & Junghöfer, 2007; Schupp, Junghöfer, Weike, & Hamm, 2003).

In a well-known study, Anderson and Phelps (2001) investigated the identification of emotional words in a rapid serial visual presentation (RSVP) paradigm. In this paradigm, the second of two targets presented in a stream of distractors is often not identified if it is presented between 100 ms and 600 ms after the presentation of the first target (Bachmann & Hommuk, 2005; Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1992, 1995). Anderson and Phelps demonstrated that the size of this so-called attentional blink effect is attenuated for emotional words. In addition, Fox, Russo, and Georgiou (2005) have shown that the attentional blink is attentuated for fearful facial expressions and that this effect is modulated by self-reported anxiety of participants. In other paradigms too, it has been shown that emotional stimuli are more often correctly identified than neutral stimuli (Gaillard, Del Cul, Naccache, Vinckier, Cohen, & Dehaene, 2006; Vuilleumier & Schwartz, 2001). Recently, Zeelenberg, Wagenmakers, and Rotteveel (2006) demonstrated that the improved visual identification of masked emotional stimuli is due to a genuine perceptual enhancement rather than one of several possible perceptual-bias or response-bias mechanisms (cf., Bowers, 1999; Wagenmakers, Zeelenberg, & Raaijmakers, 2000; Zeelenberg, Wagenmakers, & Raaijmakers, 2002).

Emotion-Induced Blindness

In addition to studies demonstrating that emotional significance has a positive influence on the perception of emotional stimuli themselves, recent findings show that emotional stimuli also influence the perception of subsequently presented neutral stimuli. For instance, several studies have shown that the presentation of an emotional stimulus in an RSVP paradigm impairs the subsequent identification of a neutral target stimulus if the two stimuli are presented in close temporal proximity (an effect that has been coined *emotion-induced blindness*; Arnell, Killman, & Fijavz, 2007; Most, Chun, Widders, & Zald, 2005; Most, Smith, Cooter, Levy, & Zald, 2007; Smith, Most, Newsome, & Zald, 2006).

Several authors have suggested that emotional influences in visual perception may be due to selective, stimulus-specific attentional processes (Vuilleumier & Schwartz, 2001; Anderson, 2005; Anderson & Phelps, 2001; Fox et al., 2001). That is, emotional stimuli, compared with neutral stimuli, may reflexively attract attention at the expense of other visual stimuli in the environment (cf. Duncan, Ward, & Shapiro, 1994). Within this conceptual

Bruno R. Bocanegra and René Zeelenberg, Department of Psychology, Erasmus University Rotterdam.

We thank Diane Pecher, Rolf Zwaan, and Björn de Koning for helpful discussions and comments on an earlier version of this article.

Correspondence concerning this article should be addressed to Bruno R. Bocanegra or René Zeelenberg, Erasmus University Rotterdam, Department of Psychology, Woudestein, T13-31, P.O. Box 1738, 3000 DR Rotterdam, the Netherlands. E-mail: bocanegra@fsw.eur.nl or zeelenberg@fsw.eur.nl

framework, one can explain both the benefits for emotional target stimuli themselves, and the deficits for competing neutral targets. If limited attentional resources are preferentially allocated to an emotional stimulus, this will enhance its identification at the expense of other stimuli that are in spatial or temporal competition with it.

Consistent with the idea that emotion enhances attention allocation, emotional effects have also been obtained in spatial cueing paradigms (e.g., Carlson & Reinke, 2008; Fox et al., 2001). In these paradigms, the emotional significance of a cue speeds up responding to a visual target when the cue directs attention toward the target spatial location (Carlson & Reinke, 2008). However, an emotional cue slows down responding when it misallocates attention to an invalid location (Fox et al., 2001). Within an attentional framework, an emotional stimulus is predicted to attract additional processing resources at the expense of a neutral stimulus when they are in spatial competition (Fox, Derakshan, & Shoker, 2008; Pourtois, Grandjean, Sander, & Vuilleumier, 2005, Pourtois, Schwartz, Seghier, Lazeyras, & Vuilleumier, 2006). Thus, the allocation and misallocation of selective attention can explain the major findings due to emotion in both spatial cueing and RSVP paradigms when visual stimuli are in spatial or temporal competition with each other.

Emotion-Induced Hypervision

Contrary to the idea of a stimulus-specific attentional benefit, however, a recent cueing study indicated that an emotional cue stimulus can also enhance visual perception even if it does not cue the spatial location of a subsequent target (Phelps, Ling, & Carrasco, 2006). In this experiment, the foveal presentation of an emotional face improved the discriminability of a peripheral visual target at a short (125-ms stimulus onset asynchrony [SOA]) cue–target temporal interval (Phelps et al., 2006). Although the task-irrelevant cue did not indicate where the target would be located or reduce the spatial uncertainty of the target, the mere presence of the emotional cue still had a beneficial effect on target identification. This finding suggests that emotion can cause a perceptual benefit that cannot be attributed to differential spatial attention allocation to emotional cues. A possible interpretation of this beneficial carryover effect is that emotional stimuli may not only attract additional attentional resources but also trigger a more general perceptual benefit that can carry over onto the processing of other information (in analogy to the emotion-induced blindness effect, this could be referred to as *emotion-induced hypervision*; cf. Poggio, Fahle, & Edelman, 1992). That is, emotional stimuli may cause an enhancement in processing efficiency in the visual system before attentional selection (Vuilleumier et al., 2004). Whereas stimulus-specific benefits due to selective attention are thought to result from top-down modulations in the visual cortex by parietal and frontal cortical areas (Pourtois et al., 2005; Pourtois et al., 2006), a more general emotional boost might be mediated by direct projections from the amygdala to visual cortical areas (Phelps et al., 2006; Vuilleumier et al., 2004). If this emotional boost outlasts the presentation duration of the emotional stimulus itself, it may carry over onto the visual processing of subsequently presented stimuli.

Aim of the Present Study

At present, it is unknown which factors are responsible for the occurrence of either emotion-induced blindness or hypervision. The difference in results between paradigms is striking and could be due to a number of factors. A direct comparison of the beneficial (Phelps et al., 2006) and the detrimental (Most et al., 2005; Most et al., 2007) effects is complicated by the fact that these studies used experimental setups that differ in many aspects. For example, Phelps et al. (2006) used pictures of fearful faces as cues and simple Gabor patches as visual targets (hence, the cue and target stimulus came from different stimulus categories). However, emotion-induced blindness effects have been obtained with either emotional words (Arnell et al., 2007; Ihssen & Keil, 2008) or emotional pictures (Most et al., 2005; Most et al., 2007; Smith et al., 2006) in RSVP studies in which emotional distractors and neutral target stimuli were of the same stimulus category. Also, the temporal uncertainty was typically much larger in RSVP studies in which the target could occur at several possible positions within a sequence of distractor stimuli, compared with the Phelps et al. (2006) study, in which the target was always presented at the same temporal position in the trial sequence (i.e., after a single cue stimulus). In contrast, the spatial uncertainty was much larger in the Phelps et al. (2006) study where the target could occur at several possible spatial locations among distractor stimuli, compared with the emotional RSVP studies in which all stimuli are presented foveally (Arnell et al., 2007; Most et al., 2005; Smith et al., 2006).

In the present study, we investigated the influence of an emotional cue word on the identification of a subsequently presented neutral target word in a masked visual identification paradigm. Until now, the Phelps et al. (2006) finding has not been extended to other experimental paradigms, nor has any study obtained both the phenomena of emotion-induced hypervision and emotion-induced blindness within a single experimental setup. We therefore explored whether both emotional carryover effects could be obtained in an experimental procedure without spatial or temporal target uncertainty (see Most et al., 2005; Phelps et al., 2006). Also, to gain insight into the underlying mechanisms, we investigated whether the occurrence of emotion-induced blindness and hypervision could be dissociated by manipulating the competition for attention between an emotional cue word and a subsequent neutral target word.

Predictions

Current two-stage models of temporal attention posit two sequential stages of stimulus identification: (1) a high-capacity sensory processing stage, in which elementary stimulus features are extracted before conscious identification, and (2) a limited-capacity attentional processing stage, in which a stimulus representation is maintained and consolidated to enable conscious report (Bachmann & Hommuk, 2005; Chun & Potter, 1995; Jolicoeur & Dell'Acqua, 1998). Whereas high-capacity Stage 1 occurs fast and automatically, limited-capacity Stage 2 involves selective processing and is more time consuming. When emotional words are presented as cues, both their Stage 1 and Stage 2 processing may be enhanced, relative to neutral cues. That is, emotional cues may temporarily enhance sensory processing and also attract additional attentional resources.

When there is a strong temporal competition, two-stage models predict that the presence of an emotional cue, compared with a neutral cue, could cause deficits in the identification of a following target. If an emotional cue receives additional Stage 2 processing, a subsequent incoming target could be denied full access to processing because it arrives while the cue is still occupying this stage. In line with previous RSVP studies, we hypothesized that an increase in Stage 2 resources allocated to processing the emotional cue would diminish the resources allocated to target processing and thus cause impairments in identification (Arnell et al., 2007; Most et al., 2005; Most et al., 2007; Smith et al., 2006). In contrast, when temporal competition is reduced an emotional cue might improve identification of a subsequent target. If an emotional cue triggers an enhancement during Stage 1 processing, the high-capacity nature of this stage could allow this facilitation to carry over onto the processing of a subsequent target (e.g., Potter, Dell'Acqua, Pesciarelli, Job, Peressotti, & O'Connor, 2005; Visser, Merikle, & Di Lollo, 2005). In this case, we hypothesized that the emotional cue temporarily increases sensory processing efficiency so that a subsequent visual stimulus may benefit from the presence of the emotional stimulus (Phelps et al., 2006).

Previous studies investigating temporal attention with neutral stimuli indicate that the detrimental effect of engaging attention on a cue on subsequent target identification depends critically on the cue–target temporal interval, as well as the visibility of the cue (Chun & Potter, 1995; Hommel & Akyurek, 2005; Raymond et al., 1992). That is, the temporal competition for attention resulting in deficits in target identification is strongest at short intervals (100–600 ms). In two-target masked identification paradigms, target detection is mostly heavily impaired by a preceding cue at an SOA of around 250 ms. This deficit gradually returns to ceiling performance at a SOA of 800 ms (Duncan, Ward, & Shapiro, 1994). In addition, it has been shown that the interfering effect of a cue stimulus on target identification depends critically on whether the cue was rendered invisible because of pattern-masking (Bachmann & Hommuk, 2005; Bachmann & Sikka, 2005; Chua, 2005; Potter, Staub, & O'Connor, 2002). In these studies, target identification performance increased as cue visibility decreased.

In two experiments, we varied the temporal interval between cue and target words, and the visibility of the cue words. We manipulated these two factors to influence the amount of competition between cues and targets and thereby the relative contribution of potentially distinct emotional modulations in visual processing (Bachmann & Hommuk, 2005; Potter et al., 2002). Because the hypothesized emotional modulations of Stage 1 and Stage 2 processing predict opposite effects of emotional cuing, we expected that, depending on the level of competition between the cue and the target, either a detrimental carryover effect or a beneficial carryover effect would be obtained (cf. Zeelenberg, Wagenmakers, & Shiffrin, 2004). More specifically, under conditions of high competition emotion-induced blindness would be expected. However, under conditions of low competition emotion-induced hypervision was expected.

Experiment 1

In our first experiment, we asked participants to identify cued target words that were presented very briefly (15–45 ms; presentation times were adjusted individually) and immediately backward masked (see Figure 1). After the mask, participants performed a two-alternative forced-choice decision on the target. This cued visual identification procedure enabled us to manipulate attentional competition between cues and targets during visual processing by varying the interstimulus interval (ISI). We expected emotional cues to affect the identification of the neutral targets differentially, depending on the level of competition between them. Specifically, we reasoned that competition would be strong at short ISIs ($<\sim$800 ms). In this case, an emotional cue might impair target identification performance because the increased attention reflexively drawn to the cue would occur at the expense of target processing. At long ISIs ($>\sim$800 ms), however, we expected that competition between the cue and target would be weak (e.g., Raymond et al., 1992) and that emotional cues might improve target identification performance. Because competition is reduced, emotional cues are less likely to "steal" processing resources from the neutral targets. Rather, an emotional cue might exert a positive influence on target identification because of a general boost in processing efficiency that carries over onto the target.

Method

Participants. Ninety-six students at Erasmus University Rotterdam in Rotterdam, the Netherlands, participated for course credit. They were native speakers of Dutch, reported normal or corrected-to-normal vision, and gave informed consent. Thirty-two participants were randomly assigned to each of three between-participants conditions (ISI: 50 ms, 500 ms, or 1,000 ms).

Stimulus materials. For the purpose of stimulus construction, we initially gathered 444 words from Hadley and MacKay (2006) and the ANEW database (Bradley & Lang, 1999). These were translated into Dutch and rated on 9-point scales in a stimulus evaluation study (n = 10) in terms of their arousal (1 = *low arousal*, 9 = *high arousal*) and valence (1 = *negative*, 9 = *positive*) using the Self-Assessment Manikin (Bradley & Lang, 1999). From this collection, we selected 104 cue words, consisting of 52 (mainly negative) high-arousal emotional words (e.g., *rape*, *torture, kill*), and 52 low-arousal neutral words (e.g., *owl*, *clock*, *shirt*). The selected emotional and neutral words were equated in terms of their number of letters (M = 7.07), mean number of

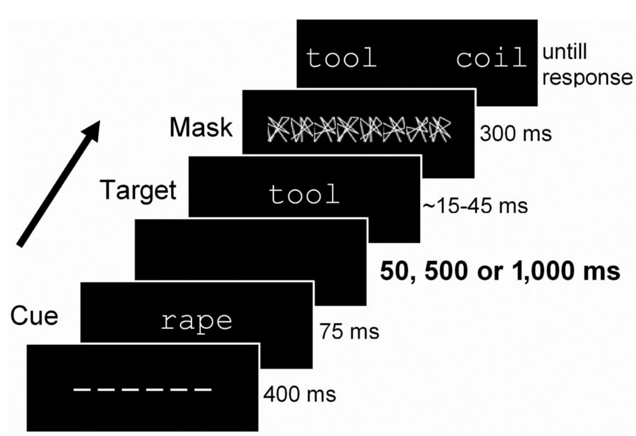

Figure 1. Illustration of the display sequences for trials in Experiment 1.

syllables (2.31 vs. 2.27), proportion of words from each of three grammatical classes (i.e., verbs, nouns, or adjectives), and mean log word frequency per million (0.946 vs. 0.958); all *p*s $> .80$. The emotional and neutral words differed in terms of both their arousal ratings (8.06 vs. 4.31) and valence ratings (3.11 vs. 5.69), with emotional cue words being more arousing and negative than neutral cue words, $t(102) = 29.34$, $p < .01$; and $t(102) = 8.16$, $p < .01$, respectively. An additional set of 104 neutral test words (mean log frequency per million = 1.17) were selected from the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995) to serve as a target and foil in the two-alternative forced-choice perceptual identification procedure.

Fifty-two word quadruplets were created, so that an emotional cue word and a neutral cue word were paired with two neutral test words that served as target and foil. Within each quadruplet, we equated the number of letters overlapping between each cue and the target and foil. A total of four counterbalanced lists were created so that, across participants, each neutral and emotional cue word within a quadruplet was used equally often as a cue and each neutral test word served both as a target and foil.

Finally, 180 words (mean log frequency per million = 1.39) were selected to serve as cue, target, or foil in a separate calibration procedure. No word was presented more than once in the experiment.

Apparatus and procedure. Stimuli were presented on a gamma-corrected Iiyama 21-inch. (53.34-cm) Vision Master monitor at a 200-Hz refresh rate and 800 × 600 pixel (Courier New 18 point font, 3°–5° visual angle). The presentation procedure for Experiment 1 is illustrated schematically in Figure 1. Each trial consisted of the presentation of a warning signal, a cue word, a blank screen (50 ms, 500 ms, or 1,000 ms), a target word, a backward mask, and two choice alternatives. All stimuli were presented in white on a black background. The mask stimuli consisted of eight mask characters that covered the entire area where words had been presented. Ten different mask characters were used, each consisting of seven randomly oriented lines. For each position in the mask, a character was sampled randomly (with replacement) from the set of 10 mask characters. After the final mask, two words were presented side by side, and participants were asked to indicate which one was the target word. For each trial, the location of the correct choice (left-hand or right-hand word) was determined randomly. Participants entered their response by pressing the z or m key on the keyboard to indicate that the left-hand or right-hand alternative corresponded to the briefly flashed target word.

The session started with four practice trials in which targets were flashed for as long as 100 ms (so that the target was clearly visible) to ensure that the requirements of the experiment were clear to the participant. Next, 60 calibration trials, subdivided in four blocks of 15 trials each, were presented to estimate the flash time, resulting in 70% correct performance. We calibrated target presentation times within a range of 15 to 100 ms (in steps of 5 ms) using an adaptive algorithm in which the presentation time in calibration block N was adjusted on the basis of performance in block $N - 1$. In a staircase procedure, the presentation time for each block was adjusted either upward or downward depending on the difference between accuracy of the previous block and the 70% performance threshold. The step size of these adjustments decreased with each consecutive block to converge onto the desired 70% performance threshold (Wagenmakers, Zeelenberg, & Raaijmakers, 2000; Zeelenberg et al., 2006). Because of this calibrated performance criterion, differences in overall performance between the different ISI conditions in Experiment 1 (and between the visibility conditions in Experiment 2) cannot be meaningfully interpreted. To assess overall performance across these conditions, we compared the target flash times to which participants had been calibrated. The average flash times used in the main experiment decreased as the ISI increased (39, 28, and 22 ms for the 50-, 500-, and 1,000-ms ISIs, respectively; *p*s $< .05$ for all least significant difference [LSD] post hoc comparisons).

The calibration trials were followed by 52 experimental trials. For each participant, 26 targets were preceded by a neutral cue and 26 targets were preceded by an emotional cue. Stimuli were presented in a different random order for each participant.

Results and Discussion

Figure 2 shows the percentages of correctly identified target words as a function of the emotional status of the cue and the ISI. As can be seen, emotional cues caused both beneficial and detrimental effects depending of the temporal interval between the presentation of the cue and the target. These conclusions were confirmed by a two-way analysis of variance (ANOVA) that was conducted on the percent correct target identification with emotional status of the cue (emotional vs. neutral) as a within-participant factor and ISI (50, 500, or 1,000 ms) as a between-participants factor. There was no significant main effect of ISI, $F(1, 93) < 1$; and a marginally significant effect of the emotional status of the cue, $F(1, 93) = 3.59$, $p < .07$. The interaction between ISI and the emotional status of the cue was significant, $F(2, 93) = 8.55$, $p < .001$, $\eta_p^2 = 0.16$. Planned comparisons showed an emotion-induced deficit in target identification when cue and target were presented at an ISI of 50 ms, $t(31) = 3.38$, $p < .01$, $d = 0.54$; and at an ISI of 500 ms, $t(31) = 2.77$, $p < .01$, $d = 0.43$; and they showed an emotion-induced benefit in target iden-

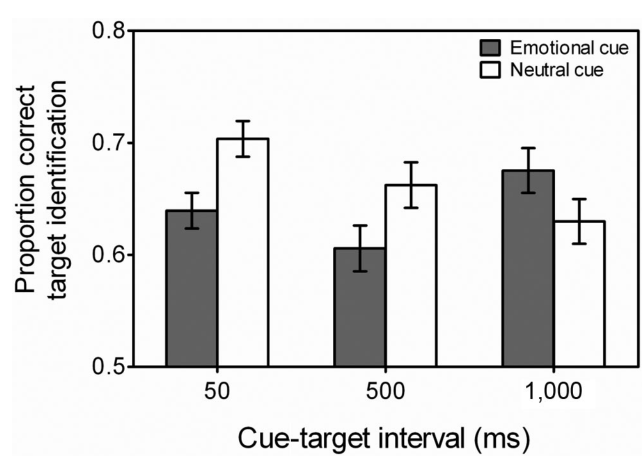

Figure 2. Percentages of correctly identified targets as a function of emotional status of the cue in Experiment 1. Error bars represent within-participant standard errors of the mean (Loftus & Masson, 1994).

tification when emotional cues were presented at an ISI of 1,000 ms, $t(31) = 2.01$, $p = .053$, $d = 0.37$.[1]

The negative carryover effects indicated that, when the cue and target are presented in close temporal proximity, the visual representations of the emotional cues have a tendency to win the competition for attentional processing, thereby impairing target identification. However, when the temporal spacing between the cue and target was increased emotional cues improve target identification. At a long ISI, the competition between cue and target is reduced and the perceptual deficit turns into a benefit (see Figure 2). In this situation, the increase in the efficiency of visual processing due to the emotional cue dominates and benefits target identification.

Experiment 2

In a second experiment, we manipulated the visibility of the cue words. On the basis of previous findings (Bachmann & Sikka, 2005; Chua, 2005; Hommel & Akyurek, 2005; Potter et al., 2002), we expected that limiting cue visibility through pattern masking would diminish competition between the cue and the target. As a consequence, we might be able to observe an emotion-induced benefit even when the cue and target are presented at close temporal proximity. To limit cue visibility, we forward-masked the cue words and presented the cue and target in immediate succession, so that the target stimulus would backward-mask the cue stimulus. We also included a condition in which a short delay of 120 ms was added after the forward-masked cue word, as well as a condition including a 120-ms delay without an additional forward mask. Previous findings indicate that both the inclusion of a short delay after the cue, as well as the removal of the forward mask, contributes to restoring cue visibility (e.g., Gaillard et al., 2006).

Previous semantic and orthographic priming studies have shown that, although the combined effect of a forward mask and a lack of temporal delay between cue and target results in a severely restricted conscious perception of the cue word, semantic processing of the cue still occurs under these conditions (Evett & Humphreys, 1981; Pecher, Zeelenberg, & Raaijmakers, 2002). A recent study indicated that emotional words rendered invisible through forward and backward masking can nonetheless differentially activate the amygdala (Naccache et al., 2005). Also, limiting stimulus visibility through pattern masking does not significantly alter early stages of sensory processing (e.g., Fahrenfort, Scholte, & Lamme, 2007). Instead, it has been shown that masking eliminates later reentrant processing to cortical areas, which is thought to maintain and consolidate visual representations. Consistent with two-stage models of temporal attention, these findings and others (e.g., Vogel, Luck, & Shapiro, 1998; Sergent, Baillet, & DeHaene, 2005), indicate that masked stimuli are able to access Stage 1 processing. However, masking severely restricts their access to Stage 2 processing (see Bachmann & Hommuk, 2005). Through masking, emotional cues are prevented from "capturing" limited-capacity Stage 2 processing (and thus prevented from impairing Stage 2 processing of a subsequent incoming target), which allows a perceptual facilitation in Stage 1 to manifest itself in target identification accuracy. We therefore expected to find an emotion-induced beneficial carryover effect in the condition in which cue visibility was severely restricted (i.e., when the prime was presented immediately before the target and preceded by a forward mask). When cue visibility was restored, we expected to find an emotion-induced detrimental carryover effect.

Method

Participants. A total of 120 students from the Erasmus University Rotterdam participated for course credit. Forty participants were assigned to each of three between-participants conditions (low, medium, and high visibility of the cue).

Stimulus materials, apparatus, and procedure. The procedure was largely identical to that of Experiment 1, except that cue words were forward-masked in the low and medium cue visibility conditions (see Figure 3). In addition, rather than using a fixed presentation time of the cue, the presentation times for cues and targets were equated to reduce cue visibility. In the low-cue-visibility condition, the cue was forward-masked and there was no delay between the offset of the cue and the onset of the target. In the medium-cue-visibility condition, the cue was also forward-masked, but a 120-ms ISI elapsed between the offset of the cue and the onset of the target. In the high-cue-visibility condition, no forward mask was presented and a 120-ms cue–target ISI was used. Pilot data indicated that the no-mask–no-gap manipulation would have reduced cue visibility to a level comparable with that of the mask–gap manipulation. Considering that these two medium visibility conditions would be less informative that the high (no mask–gap) and the low (mask–no gap) visibility conditions, we decided to run only one medium visibility condition. Flash times of the cues and targets were calibrated individually for each participant. The resulting flash times used in the main experiment increased as a function of cue visibility (36, 40, and 46 ms for the low-, medium-, and high-visibility conditions respectively, $ps < .05$ for all LSD post hoc comparisons). All other aspects of the method were identical to those of the Experiment 1 method.

Results and Discussion

As a manipulation check, we asked participants postexperimentally whether they had seen any emotional words during the experiment and to report as many as they could. In the low-cue-visibility condition, 38 of the 40 participants were unable to name a single cue word, whereas in the medium- and high-cue-visibility conditions, all participants reported at least one cue word.

A two-way ANOVA with cue status (emotional vs. neutral) as a within-participant factor and cue visibility (low, medium, and high) as a between-participants factor showed no significant main effects of cue status and cue visibility on target identification, $F(1, 117) < 1$, and $F(1, 117) = 1.13$, $p > .25$, respectively. There was, however, a significant interaction, $F(2, 117) = 10.69$, $p < .001$, $\eta_p^2 = 0.15$. Planned comparisons showed an emotion-induced benefit in target identification with low cue visibility, $t(39) = 3.20$, $p < .01$, $d = 0.56$; no significant effect with medium cue visibility, $t(39) = 1.42$, $p > .10$; and an emotion-induced deficit with high

[1] Because participants were calibrated individually to a performance criterion of 70%, post hoc contrasts between the cue–target interval conditions (Experiment 1) and between the cue-visibility conditions (Experiment 2) cannot be interpreted in a meaningful way. Hence, no such analyses were performed.

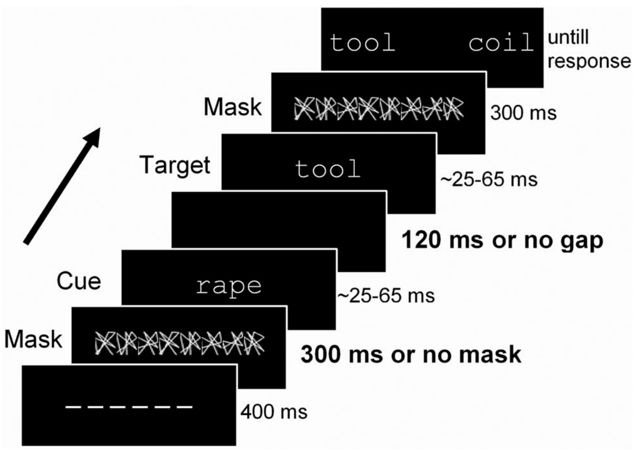

Figure 3. Illustration of the display sequences for trials in Experiment 2.

cue visibility, $t(39) = 3.51$, $p < .01$, $d = 0.51$ (see Figure 4). These findings show that emotional cue words can both improve and impair target identification when presented at close temporal proximity. It is important to note that whether emotional cues have beneficial or detrimental effects on subsequent target identification appears to depend on cue visibility.

General Discussion

In recent years, several findings in psychology and cognitive neuroscience have indicated that emotion exerts a strong influence on a wide range of different facets of human cognition, ranging from reasoning and decision making to memory, attention, and perception (Dolan, 2002; Fox et al., 2001; Öhman et al., 2001; Phelps, 2006). Behavioral studies have shown an emotional influence on the perceptual processes that initiate higher level cognitive functions. For example, it has been demonstrated that the visual identification of emotional stimuli themselves is enhanced compared with that of neutral stimuli (Anderson, 2005; Anderson & Phelps, 2001; Gaillard et al., 2006; Zeelenberg et al., 2006). It is interesting that recent studies have additionally shown that emotional stimuli sometimes improve (emotion-induced hypervision: Phelps et al., 2006) and sometimes impair (emotion-induced blindness: Arnell et al., 2007; Most et al., 2005; Most et al., 2007; Smith et al., 2006) the visual perception of subsequent neutral stimuli.

In the present study, we sought to separate the contributions of potentially distinct mechanisms underlying emotion-induced improvements and impairments in visual perception. Our results demonstrate that emotional cue words can both improve and impair threshold visual identification of subsequently presented neutral targets words. Critically, emotional cues impaired target identification when the cue and target word were presented in close temporal proximity so that there was strong temporal competition for attention between cues and targets. However, when this competition was reduced either by increasing the temporal interval between cue and target words, or by restricting cue visibility through masking at short intervals, we found that emotional cues improved target identification.

Our main results therefore provide evidence for a twofold perceptual influence due to emotion: (a) a stimulus-specific enhancement, through which emotional stimuli profit from additional attentional processing at the expense of competing stimuli, and (b) a general enhancement in the efficiency of visual processing that can carry over onto the identification of other stimuli. Although previous studies have shown that emotional stimuli can improve (Phelps et al., 2006) or impair subsequent perception (Most et al., 2005), these effects were obtained in different studies with paradigms that differed on many dimensions. In the present study, we demonstrate for the first time that emotion-induced hypervision and emotion-induced blindness can be obtained within a single paradigm, and we show under what experimental conditions these beneficial or detrimental emotional influences will manifest themselves. Moreover, we show that emotion-induced hypervision can be obtained when words are used as cues rather than faces.

Our findings that emotional cue words impair identification of a subsequently presented neutral word when the cue and target are presented in close temporal proximity (500 ms or less) extends the emotion-induced blindness effect (Most et al., 2005) to a paradigm in which only two stimuli are presented in a sequence. Previous studies have shown negative effects of an emotional stimulus on the identification of a subsequently presented neutral stimulus in RSVP paradigms in which one or more targets are presented within a stream of distractors. Detrimental carryover effects of emotional stimuli have been obtained both when the emotional stimulus was task relevant (i.e., when it was a target that had to be identified) and when the emotional stimulus was task irrelevant (i.e., when it was a distractor that had to be ignored; Ihssen & Keil, 2008; Mathewson, Arnell, & Mansfield, 2008). In the present study, the temporal uncertainty was much smaller than in RSVP studies in which a series of multiple stimuli is presented and participants do not know in advance at which point in the sequence a distractor or target will be presented. In our experiments, on each trial only two words were presented. The first word (i.e., the cue) was always task irrelevant, and the second word was always the target word that had to be identified. However, despite the fact that there was no temporal uncertainty, the negative effect of the emotional cue on target identification was still present, indicating that the detrimental influence of emotional stimuli on subsequent

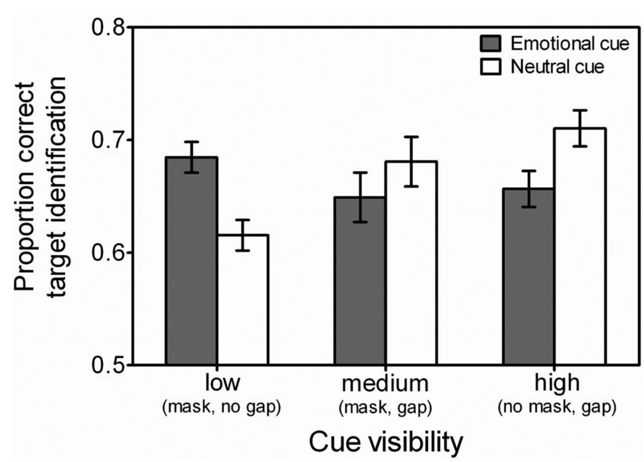

Figure 4. Percentages of correctly identified targets as a function of emotional status of the cue in Experiment 2. Error bars represent within-participant standard errors of the mean (Loftus & Masson, 1994).

visual identification is even more pervasive than previously reported studies have shown.

Previous RSVP studies have shown that the emotion-induced blindness effect is modulated by the arousal value and not the valence of the presented emotional stimuli (Ihssen & Keil, 2008; Mathewson et al., 2008). Both positive and negative arousing visual stimuli have been shown to elicit emotion-induced blindness (Most et al., 2007). In the present study, most emotional stimuli were high-arousal negative words. An interesting follow-up to the present study would be to test whether the emotion-induced hypervision effect, such as the emotion-induced blindness effect, is selectively dependent on the arousal value of the presented stimuli.

Note that we obtained detrimental emotion-induced carryover effects under temporal conditions (short ISI, visible cues) in which Phelps et al. (2006) obtained beneficial carryover effects. The present study and the Phelps et al. study, however, differ in many aspects. For example, in our experiments, spatial uncertainty was much smaller than in the Phelps et al. study. In their study, four Gabor patches (one tilted among three distractors) were presented peripherally on each trial, whereas in the present study only one centrally presented target stimulus (a word) was presented. Also, in the Phelps et al. study, cues and targets were presented multiple times, whereas in the present study each word was presented only once in the experiment. A systematic evaluation of all potentially critical factors or a combination thereof would require several experiments and is beyond the scope of the present study. One important factor, however, might be that, in the Phelps et al. study, the cue (a face) and target (a Gabor patch) were visually dissimilar. This may have reduced the amount of temporal competition between the cue and the target (see Einhäuser, Koch, & Makeig, 2007) and resulted in a beneficial carryover effect. It is interesting to note that previous RSVP studies, in which targets and distractors were visually similar and from the same stimulus category, consistently show detrimental carryover effects. In the present study, the cue and target were highly similar (both were words) and more drastic measures (i.e., long cue–target ISI or masking of the cue) were necessary to reduce the competition between cue and target for the beneficial effects of emotional cuing to become manifest.

Many studies suggest that emotional cues can enhance the allocation of spatial attention and facilitate the detection of visual targets in tasks that induce spatial uncertainty (spatial cueing paradigms; Carlson & Reinke, 2008; Fox et al., 2008; Fox et al., 2001; Pourtois et al., 2005, Pourtois et al., 2006). In the present study, however, we show that a task-irrelevant emotional cue improves subsequent perception in the absence of any spatial uncertainty as to the target presentation. To our knowledge, only one previous study has demonstrated such an emotional benefit in perception (Phelps et al., 2006). As such, the present study provides the first replication of an emotion-induced enhancement in visual perception that cannot be attributed to differential allocation of spatial attention.

We show that the beneficial and detrimental perceptual consequences of emotion appear, as we had predicted, under differing levels of temporal competition between emotional and neutral visual stimuli (Bachmann & Hommuk, 2005; Chun & Potter, 1995; Potter et al., 2002; Raymond et al., 1992), suggesting that emotion modulates distinct processing stages of visual identification (see also Schupp, Stockburger, Codispoti, Junghöfer, Weike, & Hamm, 2007). In terms of two-stage models of temporal attention, emotion may facilitate an initial high-capacity sensory processing stage in which elementary object features are extracted before overt identification (Stage 1). This facilitation can carry over to other stimuli and enhance their identification. In addition, emotion may also facilitate a subsequent limited-capacity attentional processing stage in which object representations are maintained to enable conscious report (Stage 2; Bachmann & Hommuk, 2005; Brehaut, Enns, & Di Lollo, 1999; Chun & Potter, 1995; Jolicoeur & Dell'Acqua, 1998; Potter et al., 2002; Sergent et al., 2005; Shapiro, Schmitz, Martens, Hommel, & Schnitzler, 2006). This latter process enhances the processing of emotional stimuli at the expense of neutral stimuli. Previous attentional blink findings have shown that, when consecutive visual targets compete for access to attentional resources, the extent to which attention is engaged by a first target determines the degree to which identification of the second target is impaired (Bachmann & Hommuk, 2005; Chun & Potter, 1995; Hommel & Akyurek, 2005; Jolicoeur & Dell'Acqua, 1998; Potter et al., 2002; Sergent et al., 2005; Shapiro et al., 2006). The detrimental emotional carryover effects in both of our experiments are consistent with these findings and suggest that access to Stage 2 attentional processing, and perhaps also overt identification, may be necessary prerequisites for emotion-induced blindness to occur (Arnell et al., 2007; Most et al., 2005; Most et al., 2007; Smith et al., 2006).

Could a single attentional mechanism account for both the emotion-induced deficits and benefits found in the present study? Although the detrimental effect of emotional cues on target identification is consistent with enhanced Stage 2 attentional processing of the emotional cues (see Mathewson et al., 2008), it is difficult to see how an emotion-induced increase in selective attention can account for the beneficial carryover effects in our experiments. A Stage 2 enhancement is unlikely to have consequences when stimuli are not in temporal competition for attentional resources (Chun & Potter, 1995; Potter et al., 2002). On the other hand, enhanced Stage 1 processing is predicted to benefit the emotional stimulus and subsequent targets, even if the emotional stimulus does not reach attentional stages of visual processing (see Potter et al., 2005; Visser, Merikle, & Di Lollo, 2005). Recent masking studies indicate that unconscious emotional words can be processed up to semantic levels (Naccache et al., 2005) and that the unconscious processing of affective valence might contribute to conscious identification performance (Gaillard et al., 2006). Consistent with these studies, the results of Experiment 2 suggest that emotional words that are strongly restricted in visibility through masking can nonetheless exert a modulating influence on visual performance. Our findings suggest that emotional stimuli do not need to access overt attentional stages of visual identification to enhance visual processing. However, if they are overtly identified, they are likely to impair perception if a subsequent stimulus is presented at a short temporal interval (see Ihssen, Heim, & Keil, 2007).

To conclude, our findings provide evidence for distinct mechanisms underlying beneficial and detrimental carryover effects of emotion on subsequent perception. Specifically, our results suggest that, when there is limited time to identify visual events, emotional significance boosts the efficiency of visual processing and enhances the allocation of attention to emotional events at the expense of competing visual information.

References

Anderson, A. K. (2005). Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology: General, 134,* 258–281.

Anderson, A. K., & Phelps, E. A. (2001). Lesions of the human amygdala impair enhanced perception of emotionally salient events. *Nature, 411,* 305–309.

Arnell, K. M., Killman, K. V., & Fijavz, D. (2007). Blinded by emotion: Target misses follow attention capture by arousing distractors in RSVP. *Emotion, 7,* 465–477.

Baayen, R. H., Piepenbrock, R., & Gulikers, L. (1995). *The CELEX lexical database.* Philadelphia: Linguistic Data Consortium.

Bachmann, T., & Hommuk, K. (2005). How backward masking becomes attentional blink. *Psychological Science, 16,* 740–742.

Bachmann, T., & Sikka, P. (2005). Perception of successive targets presented in invariant-item streams. *Acta Psychologica, 120,* 19–34.

Bowers, J. S. (1999). Priming is not all bias: Commentary on Ratcliff and McKoon (1997). *Psychological Review, 106,* 582–596.

Bradley, M. M., & Lang, P. J. (1999). *Affective norms for English words: ANEW.* Gainesville, FL: University of Florida Press.

Brehaut, J. C., Enns, J. T., & Di Lollo, V. (1999). Visual masking plays two roles in the attentional blink. *Perception and Psychophysics, 61,* 1436–1448.

Carlson, J. M., & Reinke, K. S. (2008). Masked fearful faces modulate the orienting of covert spatial attention. *Emotion, 8,* 522–529.

Chua, F. K. (2005). The effect of target contrast on the attentional blink. *Perception and Psychophysics, 67,* 770–788.

Chun, M. M., & Potter, M. C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 109–127.

Dolan, R. J. (2002). Emotion, cognition, and behavior. *Science, 298,* 1191–1194.

Duncan, J., Ward, R., & Shapiro, K. (1994). Direct measurement of attentional dwell time in human vision. *Nature, 369,* 313–315.

Einhäuser, W., Koch, C., & Makeig, S. (2007). The duration of the attentional blink in natural scenes depends on stimulus category. *Vision Research, 47,* 597–607.

Evett, L. J., & Humphreys, G. W. (1981). The use of abstract graphemic information in lexical access. *Quarterly Journal of Experimental Psychology, 33*A, 325–350.

Fahrenfort, J. J., Scholte, H. S., & Lamme, V. A. F. (2007). Masking disrupts reentrant processing in human visual cortex. *Journal of Cognitive Neuroscience, 19,* 1488–1497.

Fox, E., Derakshan, N., & Shoker, L. (2008). Trait anxiety modulates the electrophysiological indices of rapid spatial orienting towards angry faces. *Neuroreport, 19,* 259–263.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General, 130,* 681–700.

Fox, E., Russo, R., & Georgiou, G. A. (2005). Anxiety modulates the degree of attentive resources required to process emotional faces. *Cognitive, Affective, and Behavioral Neuroscience, 5,* 396–404.

Gaillard, R., Del Cul, A., Naccache, L., Vinckier, F., Cohen, L., & Dehaene, S. (2006). Nonconscious semantic processing of emotional words modulates conscious access. *Proceedings of the National Academy of Sciences, USA, 103,* 7524–7529.

Hadley, C. B., & MacKay, D. G. (2006). Does emotion help or hinder immediate memory? Arousal versus priority-binding mechanisms. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32,* 79–88.

Hommel, B., & Akyurek, E. G. (2005). Lag-1 sparing in the attentional blink: Benefits and costs of integrating two events into a single episode. *Quarterly Journal of Experimental Psychology, 58*A, 1415–1433.

Ihssen, N., Heim, S., & Keil, A. (2007). The costs of emotional attention: Affective processing inhibits subsequent lexico-semantic analysis. *Journal of Cognitive Neuroscience, 19,* 1932–1949.

Ihssen, N., & Keil, A. (2008). The costs and benefits of processing emotional stimuli during rapid serial visual identification. *Cognition and Emotion, 23,* 296–326.

Jolicoeur, P., & Dell'Acqua, R. (1998). The demonstration of short-term consolidation. *Cognitive Psychology, 36,* 138–202.

Keil, A., Ihssen, N., & Heim, S. (2006). Early cortical facilitation for emotionally arousing targets during the attentional blink. *BMC Biology, 4,* 1–13.

Kissler, J., Herbert, C., Peyk, P., & Junghöfer, M. (2007). Buzzwords: Early cortical responses to emotional words during reading. *Psychological Science, 18,* 475–480.

Lang, P. J., Bradley, M. M., Fitzsimmons, J. R., Cuthbert, B. N., Scott, J. D., Moulder, B., & Nangia, V. (1998). Emotional arousal and activation of the visual cortex: An fMRI analysis. *Psychophysiology, 35,* 199–210.

Loftus, G. R., & Masson, M. J. (1994). Using confidence intervals in within-subject designs. *Psychonomic Bulletin and Review, 1,* 476–490.

Mathewson, K. J., Arnell, K. M., & Mansfield, C. A. (2008). Capturing and holding attention: The impact of emotional words in rapid serial visual presentation. *Memory and Cognition, 36,* 182–200.

Morris, J. S., Friston, K. J., Buchel, C., Frith, C. D., Young, A. W., Calder, A. J., et al. (1998). A neuromodulatory role for the human amygdala in processing emotional facial expressions. *Brain, 121,* 47–57.

Most, S. B., Chun. M. M., Widders, D. M., & Zald, D. H. (2005). Attentional rubbernecking: Cognitive control and personality in emotion-induced blindness. *Psychonomic Bulletin and Review, 12,* 654–661.

Most, S. B., Smith, S. D., Cooter, A. B., Levy, B. N., & Zald, D. H. (2007). The naked truth: Positive arousing distractors impair rapid target perception. *Cognition and Emotion, 21,* 964–981.

Naccache, L., Gaillard, R., Adam, C., Hasboun, D., Clémenceau, S., Baulac, M., et al. (2005). A direct intracranial record of emotions evoked by subliminal words. *Proceedings of the National Academy of Sciences USA, 102,* 7713–7717.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General, 130,* 466–478.

Pecher, D., Zeelenberg, R., & Raaijmakers, J. G. W. (2002). Associative priming in a masked perceptual identification task: Evidence for automatic processes. *Quarterly Journal of Experimental Psychology, 55*A, 1157–1173.

Phelps, E. A. (2006). Emotion and cognition: Insights from studies of the human amygdala. *Annual Review of Psychology, 57,* 27–53.

Phelps, E. A., Ling, S., & Carrasco, M. (2006). Emotion facilitates perception and potentiates the perceptual benefits of attention. *Psychological Science, 17,* 292–299.

Poggio, T., Fahle, M., & Edelman, S. (1992). Fast perceptual-learning in visual hyperacuity. *Science, 256,* 1018–1021.

Potter, M. C., Dell'Acqua, R., Pesciarelli, F., Job, R., Peressotti, F., & O'Connor, D. H. (2005). Bidirectional semantic priming in the attentional blink. *Psychonomic Bulletin and Review, 12,* 460–465.

Potter, M. C., Staub, A., & O'Connor, D. H. (2002). The time course of competition for attention: Attention is initially labile. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 1149–1162.

Pourtois, G., Grandjean, D., Sander, D., & Vuilleumier, P. (2005). Electrophysiological correlates of rapid spatial orienting towards fearful faces. *Cerebral Cortex, 14,* 619–633.

Pourtois, G., Schwartz, S., Seghier, M. L., Lazeyras, F., & Vuilleumier, P. (2006). Neural systems for orienting attention to the location of threat signals: An event-related fMRI study. *Neuroimage, 31,* 920–933.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance, 18,* 849–860.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1995). Similarity determines the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 653–662.

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2003). Emotional facilitation of sensory processing in the visual cortex. *Psychological Science, 14,* 7–13.

Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2007). Selective visual attention to emotion. *Journal of Neuroscience, 27,* 1082–1089.

Sergent, C., Baillet, S., & Dehaene, S. (2005). Timing of the brain events underlying access to consciousness during the attentional blink. *Nature Neuroscience, 8,* 1391–1400.

Shapiro, K., Schmitz, F., Martens, S., Hommel, B., & Schnitzler, A. (2006). Resource sharing in the attentional blink. *Neuroreport, 17,* 163–166.

Smith, S. D., Most, S. B., Newsome, L. A., & Zald, D. H. (2006). An emotion-induced attentional blink elicited by aversively conditioned stimuli. *Emotion, 6,* 523–527.

Visser, T. A. W., Merikle, P. M., & Di Lollo, V. (2005). Priming in the attentional blink: Perception without awareness? *Visual Cognition, 12,* 1362–1372.

Vogel, E. K., Luck, S. J., & Shapiro, K. L. (1998). Electrophysiological evidence for a postperceptual locus of suppression during the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 1656–1674.

Vuilleumier, P., Richardson, M. P., Armony, J. L., Driver, J., & Dolan, R. J. (2004). Distant influences of amygdala lesion on visual cortical activation during emotional face processing. *Nature Neuroscience, 7,* 1271–1278.

Vuilleumier, P., & Schwartz, S. (2001). Emotional facial expressions capture attention. *Neurology, 56,* 153–158.

Wagenmakers, E.-J., Zeelenberg, R., & Raaijmakers, J. G. W. (2000). Testing the counter model for perceptual identification: Effects of repetition priming and word frequency. *Psychonomic Bulletin and Review, 7,* 662–667.

Zeelenberg, R., Wagenmakers, E.-J., & Raaijmakers, J. G. W. (2002). Priming in implicit memory tasks: Prior study causes enhanced discriminability, not only bias. *Journal of Experimental Psychology: General, 131,* 38–47.

Zeelenberg, R., Wagenmakers, E.-J., & Rotteveel, M. (2006). The impact of emotion on perception: Bias or enhanced processing? *Psychological Science, 17,* 287–291.

Zeelenberg, R., Wagenmakers, E.-J., & Shiffrin, R. M. (2004). Nonword repetition priming in lexical decision reverses as a function of study task and speed stress. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30,* 270–277.

Received April 18, 2008
Revision received May 15, 2009
Accepted August 3, 2009 ■